CROP RESIDUE AS OPTIMUM FEED SOURCING FOR LIVESTOCK KEPT UNDER FREE RANGE CONDITIONS WITHIN THE BLUE NILE BASIN OF SUDAN

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ABSTRACT:

The present study was initiated show that the best feed sourcing for animal production could crop-livestock under rangeland conditions of arid environment within the Nile basin ecosystem. For crop-livestock production systems, livestock water productivity (LWP) was used to indicate water utilized by the animal converted to useful products. Parameters measured were biomass availability from rangelands and crop residues, supply versus demand for the different animal species and treated crop residues to improve animal performance. Trends in rangeland productivity, crop residue biomass and animal's number and herd structure were measured through the years 2014 – 2018 in seven localities of Sennar state. Total biomass in the form of crop residues and biomass from range was calculated to determine the livestock demands during the dry season; this was done by utilizing Tropical livestock unit (TLU) equivalents and basal metabolic rates. Rangeland status was estimated using remote sensing. using multiple sets of Sentinel-2 and Landsat images (in case of cloud cover in the Sentinel-2 image). Crop production was projected for the summer season from the 'Ministry of Agriculture', Further available crop residues were calculated as: 1kg sorghum seed gives 3kg sorghum straw, 1kg millet seed gives 3 kg straw, 1kg ground nut pod gives 2kg straw.

The biomass demand was calculated based on the data from Arab Organisation for Agricultural Development that annual animal unit demand is 2.4 tons. This was translated to the biomass demand of approximately 6.5 kg per day per animal unit. The International Livestock Research Institute (ILRI) estimation of animal maintenance energy of 11,000 Kcal per LTU per day for grazing cattle in Africa, for maintenance energy, would require about 5 kg per tropical livestock unit per day of feed for maintenance. The amount of evapotranspiration required to produce this feed would be about 1.25 cubic meters per TLU per day or 450 cubic meters per tropical livestock unit per year. This compares with 25–50 liters a day or 9–18 cubic meters per tropical livestock unit per year for drinking water. Hence for each locality biomass demand was calculated as: No. of AU in the locality x 6.5 kg dry matter/day. Animal experimentation utilized dairy goats fed with straws treated with 5% urea and Student t-test was used to obtain the significance between the control and treated animals.

The results showed that contribution of crop residue to the biomass was very important and increased over the years for Abu Hougar it was maintained around 90%, for El Dali increased from 3% to 888% in year 2018. For El Dinder, El Souki and Sinnar increased to reach 454%, 775%, 219% respectively in the year 2018. However, Singa showed a decline in crop residue from 526 to 163%. Availability of the biomass showed high variability among the localities. Animal's number changed slightly over the years. Except for Sharg Sinnar. Sheep population was the highest while camels were the lowest in all localities, but herd structure was not the same where cattle, sheep and goats were comparable at El Souki and Singa. Camels and goats were comparable in El Dinder only. Abu Hougar and El Dali showed lower population of cattle and goats. At Sinnar, goats and cattle population was nearly the same. Sharg Sinnar showed comparable ratios for sheep, cattle and goats.

As for animal experimentation where dairy goats were used to test the crop residue treated with urea on food intake and milk yield, it was found that while food intake decreased significantly ($P<0.05$), milk yield increased significantly ($P<0.001$). It could be concluded that for croplivestock-water ecological system, crop residues as feed sourcing is considered the optimum biomass supply for animals during the summer season where there is no additional water is required, livestock water productivity (LWP) could be increased with better management of soil degradation, water runoff and rangeland conservation.

KEYWORDS: Livestock Production, Rangeland, Crop Residue

1- INTRODUCTION

Livestock production systems are defined in terms of aridity and the length of the growing season (Seré and Steinfeld, 1995; van Breugel *et al.*, 2010). Rain-fed production systems cover about 94 per cent of the basin, of which about 61 per cent is classified as livestock-dominated or grazing land and about 33 per cent as mixed crop–livestock production. Livestock are kept virtually wherever crops are grown, but vast areas of rangeland are not suitable for crop production, leaving animal production as the only viable form of agriculture, even if at very low levels of intensity. Irrigated areas are small amounting to less than 2 per cent of the land area, but even there, livestock are typically important assets for irrigation farmers (Faki *et al.*, 2008; Peden *et al.*, 2007).

The Nile's livestock production systems are dispersed unevenly across the basin, with arid systems concentrated in the northern two-thirds of the basin, an area occupied largely by Sudan and Egypt. Mixed crop–livestock production systems are common in the southern countries around the great lakes and in the Ethiopian Highlands. Irrigated systems are found mostly in the Nile Delta and along the banks of the Nile River in Sudan. Most of the Nile Basin's livestock reside in Sudan, where they sustain millions of poor farmers and herders, contribute about 20 per cent of national GDP, and form a significant part of Sudan's non-oil exports (Faki *et al.*, 2008; Peden *et al.*, 2007). The belt's link to the Nile Basin is strong in terms of livestock production in schemes irrigated from the Nile, livestock mobility between rain-fed and irrigated areas and livestock trade with other Nile Basin countries (Faki *et al.*, 2008). For example, the only practical way livestock can access vast grazing lands during the more favourable rainy season is by having access to the relatively nearby Nile's blue water system in dry periods. Transhumance and nomadic modes of production, thriving on natural pastures, is the ruling practice, but cropland expansion increasingly impedes pastoral mobility.

Livestock water productivity (LWP) in the central belt of Sudan showed that in most of the belt there is a severe drinking water shortage for both animals and people. Livestock also suffer from feed shortages. LWP is low near watering points, because high animal concentration has degraded the nearby pastures. LWP is also low far from watering points because lack of water prevents animals from accessing otherwise available feed (Kaki *et al*., 2008). Feed sourcing is found very important for increasing LWP, the prime option is the use of crop residues and byproducts. When crops are grown for human food, taking advantage of their residues and byproducts imposes little or no additional water cost beyond what the crop itself requires. In contrast, using irrigation water to produce forage results in a comparatively high water cost and, thus, relatively low LWP (Peden *et al.*, 2007).

2. MATERIALS AND METHOD

2. AREA OF STUDY

The area of the study lies in Sinnar state located within the Savanna belt of south central Sudan with its characteristic long dry season. Sinnar State is surrounded by Al-Gazira State in the north, The Blue Nile State in the south, Al-Gedaref State and the Sudanese Ethiopian borders in the east, and the White Nile State and the Upper Nile State of South Sudan in the west. Singa is the capital of Sennar State; another significant town is Sennar, the largest city in the state. Other commercial towns include El-El Soukii and El-Dinder. 7 localities that constituted the state were investigated.

2.1 BIOMASS MEASUREMENT

Total biomass in the form of Crop residues and biomass from range was calculated to determine the livestock demands during the dry season. One advantage of using crop residues for feed lies in the fact that this feed source requires little or no additional water for production compared with that used to produce the crop. Crop Acreage was estimated and crop production was projected for the current summer season for the 'Ministry of Agriculture', using multiple sets of Sentinel-2 and Landsat images (in case of cloud cover in the Sentinel-2 image). Further available crop residues were calculated for the different crops utilizing the following table (2.1)

2.2. ANIMAL DEMAND FROM BIOMASS

The Biomass Demand was calculated at 'Locality Level' for the different states of the study area. The Biomass Demand was calculated based on the data from Arab Organisation for Agricultural Development which says that annual animal unit demand is 2.4 tonne. This translates to the biomass demand of approximately 6.5 kg per day per animal unit. The following table shows the state wise summary of daily and annual biomass demand within the study area-
Calculation biomass demands from biomass to meet animals' requirements was done as follows:

(i) A synthesis by the International Livestock Research Institute (ILRI) suggests an estimate of animal maintenance energy of 11,000 Kcal per tropical livestock unit (LTU) per day for grazing cattle in Africa, for maintenance energy, would require about 5 kg per tropical livestock unit per day of feed for maintenance. The amount of evapotranspiration required to produce this feed would be about 1.25 cubic meters per tropical livestock unit per day or 450 cubic meters per tropical livestock unit per year. This compares with 25– 50 liters a day or 9–18 cubic meters per tropical livestock unit per year for drinking water (table 2.2). The actual energy use and water for feed will be about double this when factoring in growth, work, lactation, reproduction, herd structure, and thermoregulation per animal unit.

(ii) Biomass Demand per Locality = No. of AU in the locality x 6.5 Kg Dry Matter/day

Table 3.2.3 Tropical livestock unit equivalents and basal metabolic rates

Species	Tropical livestock units per head	Basal metabolic unit (calories per tropical livestock unit)	species	Tropical livestock units per head	Basal metabolic unit (calories per tropical livestock unit)
Camel	1.4	4,046	Pig	0.20	6,581
Cattle	1.0	4,401	Sheep or goats	0.10	7,826
Donkey	0.5	5,234	Poultry (chicken)	0.01	13,917

Source: FAO 2004; Kleiber 1975; Jahnke 1982.

2.3 RANGELAND STATUS

Using remote sensing for NDVI, rangeland biomass, (non-crop, non-forest) (NCNF Vegetation) was calculated during Late August/September 2018 (Sq km) compared with percentage cover for the same season and compared with those during October/ November. To find out about the available food resources in each locality, total crop residues and rangeland biomass (noncrop/non forest vegetation) (tons) for the summer season was calculated.

Table 3.2.1 crop yield of crop residue

Crop	**Amount of Produce**	**Crop Residues**
Sorghum	1 Kg Seeds	3 Kg Straw
Millet	1 Kg Seeds	3 Kg Straw
Ground Nut	1 Kg Pods	2 Kg Straw

3. RESULTS

3.1 YEAR 2018

3.1.1ANIMAL POPULATION (YEAR 2018)

As shown in table 3.1.1 Sharg Sinnar hosted more than 1 million number of goats, then sheep (~107,000) followed by cattle (~97,000) then camels with much lower number (~7). In Sinnar cattle and goats showed similar numbers (~195,000) with higher numbers obtained in sheep (~300,000) then camels (~11,000). In El Dinder, highest population was shown by sheep (~700,000), then goats and camels with nearly similar numbers (~300,000) and finally cattle (~179,000). Sheep also showed the highest population (~200,000) in Singa but with lesser than that obtained in El Dinder, cattle came next (~88,000) then goats (~400,000) and finally camels (~9,000). In Abu Hougar, sheep was still the highest (~900,000) population than goats (~200,000) and cattle (~100,000), then camels (~17,000). In El Dali sheep population reached more than two millions with lesser population for goats (~700,000), cattle (~300,000) and camels (~133,000). In El Souki, sheep still kept higher population at ~300,000, then cattle (~120,000), and goats (~92,000) and camels showing much lower values (3,000).

Generally, El Dali hosted more than 3 million head of animals, then El Dinder and Abu Hougar hosting more than 1 million of animal population with sheep contributing for much of the population. Then Sinnar with more than 700,000, then El Suki (~500,000) and Sharg Sinnar (~300,000).

3.1.2 DAILY AND ANNUAL DEMAND FOR BIOMASS

Animal demand of biomass could be related to type and number, as shown by table 3.1.2, in Abu Hougar camels had the largest number and hence highest consumption (~400,000 tons), cattle came second with lower demand (~200,000), sheep and goats with more than 1 million in number but being small ruminants with less demand (~124,000). In El Dali, cattle with highest number and hence highest biomass demand (~500,000 tons), than camels (~300,000 tons) with less numbers. Sheep and goats with more than 3 million heads but with lesser demands (~156,000 tons). In El Dinder, similar observations were obtained for numbers versus demands ~718,000, 297,000, ~466,000 tons for camels, cattle and sheep and goats respectively.In El Suki cattle with lower population than sheep and goats but showed higher demands (~199,000 tons) compared to sheep and goats (~183,000 tons). Camels showed lower demands (~8000tons) due its lower population. In Singa, cattle with highest number showed the highest demand (~146,000 tons), compared to camels with very low number and hence lower demand (~21,000 tons), with higher number showed higher demands (~123,000). Similar trends were shown in Sinnar, cattle had higher (~324,000 tons) demand, then sheep and goats (~219,000 tons), then camels (~27,000 tons).
Generally demands for biomass in the different localities ranged from than 2 million tons for El Dali and more than 1 million tons for El Dinder to thousands tons for the other localities: Abu Hougar (~700,000),Sinnar (~500,000 tons), Sharg Sinnar and Singa (~400,000), then El Souki (~300,000 tons).

Table 3.1.1 Animal population distribution in the different localities in Sinnar state (2018)

Locality	Cattle	Sheep	Goats	Camels	Total
Shargh sinnar	97,737	107,279	1,211,901	7,128	333,336
Sinnar	195,456	305,483	195,233	11,643	707,816
El Dinder	179,277	729,736	316,656	302,944	1,528,615
Singa	88,060	224,859	43,646	8,996	365,563
Abu Hougar	122,982	952,159	220,769	17,264	1,313,176
El Dali	326,418	2,710,736	725,376	133,520	3,896,051
El Souki	120,219	312,004	92,941	3,706	528,871

Table 3.1.2 Animals daily and annual demand during the year 2018

Localities	Animals	Daily Biomass Demand (Kg)	Annual Biomass Demand (Tonnes)
Abu Hougar	Camels N =172,64	1,23,7807	451,799
	Cattle N =122,982	559570	204,243
Total	Goats and sheep N =1,172,928	341819	124,764 **780,806**
El Dali	Camels N=172,64	867885	316,778
	Cattle N=326,418	1485203	542,099
Total	Goats and sheep N =3,436112	4278348	156,1597 **2,420,474** 718736.5
El Dindir	Camels N=302,944	1969141	
	Cattle N=179,277	815712	297735
Total	Goats and sheep N =1,046,392	1277981	466463 **1,482,934**
El Souki	Camels N=3706	24,094	8,794
	Cattle N=120,219	546,997	199,654
Total	Goats and sheep N =404,945	502,264	183,326 **391,745** 16,913
Sharq Sinnar (Eastern Sinnar	Camels N=7128	46337	
	Cattle N= 977,37	444704.5	162,317
Total	Goats and sheep N =1,319,180	265502.4	96,908 **444,732** 21,343
Sinja	Camels N = 8,996	58476	
	Cattle N = 880,60	400675	146,246
Total	Goats and sheep N =420,092	337710	123,264 **290,854** 27,623
Sinnar	Camels N= 116,43	75680	
	Cattle N= 195,456	889328	324,604
Total	Goats and sheep N = 924,969	600170.8	219,062 **571,289**

3.1. 3 BIOMASS SOURCES FROM CROP RESIDUES AND RANGELAND

Biomass sources from rangeland and crop residues is shown in table 3.1.3 for the year 2018, it could be seen that for most of the localities, crop residues provide most of the biomass El Dali, El Soukii and EL Dinder then Sinnar and Singa providing more than 100%. 90% for Abu Hougar and 50% for Sharg Sinnar (Table 3.1.3)

Table 3.1.3 Biomass sources from rangeland and crop residues (Ton) at localities of Sinnar state in 2018

LOCALITY	Projected Crop Residue (Summer Season)	Projected Biomass from Rangelands (NCNF Vegetation Summer Season)	Percent crop residue
	Ton	**Ton**	**Percent (%)**
Abu Hougar	3,878,862	429,968	90
El Dali	7,168,750	807,421	888
El Dindir	8,075,000	148,0631	454
El Souki	4,350,000	560,600	775
Sharq Sinnar (Eastern Sinnar)	346,250	689,750	50
Sinja	2,537,500	155,483	163
Sinnar	3,100,000	141,445	219

3.2 YEAR 2017

3.2.1 ANIMAL POPULATION

As shown in table 3.2.1, animals' type contributed with different numbers in the different localities, in Sharg Sinnar, sheep and goats showed similar higher numbers (~10,000), followed by cattle (~900,000) and finally camels (~7,000). In Sinnar cattle and goats showed similar numbers (~191,000), sheep showed the highest (~300,000) and camels, the lowest (~11,000). In El Dinder, sheep showed the highest population (~700,000), goats and camels nearly the same (~300,000) the cattle (~175,000). In Singa, sheep still showing the highest (200,000) population, then cattle (~863,000) and finally goats (~42,000) and camels (~8,000). In Abu Hougar, sheep still contributing the highest number (~900,000), the goats (~200,000) and cattle (120,000), with lowe number for camels (~17,000). In El Dali, sheep reached more than 2 millions, goats more than 700,000, cattle 300,000 and camels more than 130,000 which is the highest compared with other localities, sheep was still keeping the highest population in El Souki (~305,000),followed by cattle (~117,000) and goats (~91,000), then camels (~3,000).
Generally the highest animals' population were obtained in El Dali with more than 3 million heads, then El Dinder and Abu Hougar with more than 1 million heads, then Sinnar (600,000) and El Souli (500,000) then Sharg Sinar and El Dinder (~300,000).

3.2.2 DAILY AND ANNUAL DEMAND FOR BIOMASS

As shown by table 3.2.2 demands for biomass as daily (kg) or annually (tons) could be matched with animal number, hence, as shown in Abu Hougar that camels with larger population had greater demand (~40 tons) compared to cattle (~20 tons) with lesser population. Sheep and goats were more than million heads and their demands was more than 500,000 tons of biomass. For El Dali, higher demands were obtained for cattle (~116,000 tons) than camels (~47,000 tons), while sheep and goats number exceeded 3 millions with higher demands (~235,000 tons), which means that small ruminants in the locality could had other food supply. In El Dinder, camels with higher numbers than cattle showed higher biomass demands (~650,000 tons) than cattle (~291,000), for small ruminants the demands were higher (~457, 000 tons) due to their large numbers. For Sharg Sinnar, cattle showed higher demands (~159,000 tons) compared with camels (16,000 tons) which showed very much less numbers, sheep and goats showed lower demands (~9,000 tons) due to their low number although higher than camels but consume less.

In Singa, higher demands were observed for cattle (~143,000 tons) compared with less population for camels (~20,000 tons) and higher population of sheep and goats demands (~120,000 tons). In Sinnar same observations were obtained for cattle (~318,000 tons), camels (~27,000) small ruminants (~214,000tons).

Generally El Souki and El Dinder hosted the highest biomass demands with more than 1tons, then Abu Hougar and Sinnar, more than 500,000 tons, then El Dali 400,000 tons and the rest about 200,000 tons.

Table 3.2.1 Animal population distribution in the different localities of Sinnar (Year 2017)

Locality	Cattle	Sheep	Goats	Camels	Total
Shargh Sinnr	958,20	105,176	118,814	6,989	326,800
Sinnar	191,624	299,493	191,405	11,414	693,937
El Dinder	175,762	715,428	310,447	297,004	1,498,642
Singa	863,33	220,450	42,791	8,819	358,395
Abu Hougar	120,571	933,489	216,440	16,925	1,287,427
El Dali	320,017	2,657,584	711,153	130,902	3,819,658
El Souki	117,862	305,886	91,118	3,634	518,501
Total	95,820	105,176	118,814	6,989	326,800

Table 3.2. 2. Animals daily (kg) and annual (tone) demand during the year 2017

Localities	Animals	Daily Biomass Demand (Kg)	Annual Biomass Demand (Tones)
Abu Hougar	Camels N =169,25	110,018	40,156
	Cattle N= 120,571	54,859	20,023
Total	Goats and sheep N =1,149,929	1,438,635	525,101 **595,282**
El Dali	Camels N= 169,25	130,902	47,779
	Cattle N= 320,017	320,017	116,806
Total	Goats and sheep N = 3,368,737	645,301	235,535 **400,121**
El Dindir	Camels N = 297,004	1,782,028	650,440
	Cattle N = 175,762	799,718	291,897
Total	Goats and sheep N =1,025,875	1,252,921	457,316 **1,399,653** 8,622
El Souki	Camels3634	23,622	
	Cattle117,862	536,272	195,739
Total	Goats and sheep N =397,004	23,622	8,622 **1,974,583** 16,581

Sharq Sinnar (Eastern Sinnar	Camels N = 6,989	45,428	
	Cattle N= 958,20	435,984	159,134
Total	Goats and sheep N =223,990	260,296	9,5008 **270,724**
Sinja	Camels N =8,819	57,329	20,925
	Cattle N=863,33	392,818	143,378
Total	Goats and sheep N = 263,241	331,088	120,847 **285,151**
Sinnar	Camels N= 114,14	74,196	27,081
	Cattle N= 958,20	871,890	318240.1
Total	Goats and sheep N = 490,898	588,402	214,766 **560,088**

3.2.3 BIOMASS FROM RANGELANDS AND CROP RESIDUES

Crop residues for the summer season showed higher percentages for Singa (315%), (92%) for Abu Hougar, (81%), with very lower percentages for the rest of the localities. On the other hand, biomass from range land was highest for El Dali and EL Dinder then Sinnar and Sharg Sinnar, El Souki with Singa showing the lowest biomass from range land (Table 3.2.3)

Table 3.2.3 Biomass sources from crop residues and rangeland (Ton) at Sinnar state in 2017

LOCALITY	Projected Crop Residue (Summer Season)	Projected Biomass from Rangelands (NCNF Vegetation Summer Season)	Percent crop residue
	Ton	**Ton**	**Percent (%)**
Abu Hougar	562,036	609,351	92
EL El Dali	115,9188	34,143,292	3.4
El Dindir	780,299	32,426,206	2.4
El Souki	594,012	726,688	81
Sharq Sinnar (Eastern Sinnar)	169,871	3,623,360	4.6
Sinja	430,555	136,315	315
Sinnar	580,341	17,524,934	3.3

3.3 YEAR 2016

3.3.1 ANIMAL POPULATION

Table 3.3.1 shows Animal distribution in different localities in Sinnar state during the year 2016. In Sharg Sinnar while sheep and goats showed the highest number (~ 100,000), cattle came next (~93,000) and finally camels (~6,000). In Sinnar sheep

were the highest in number (~293,000), while goats and cattle showed nearly the same number (~187,000), and camels showed the least (~11,000). In El Dinder, sheep also showed the highest number (~700,000) then goats (~300,000) with camels having higher number (~290,000) than cattle (~179,000). The same was observed in Singa for sheep and camels but here cattle were higher (~) in number than goat (~). In Abu Hougar, sheep were the highest (~) followed by goats (~), camels (~) and finally cattle (~). In El Dali, same observations were obtained but cattle were higher (~) than camel (~), El Souki showed same observations as El Dali.

3.3.2 DAILY AND ANNUAL DEMAND FOR BIOMASS

As shown by table 3.3.2. In Abu Hougar, daily and annual demands by animals showed that sheep and goats had the highest demand followed by camels, then cattle. In El Dali, sheep and goats also showed the highest demand, followed by cattle then camels. In El Dinder, El Souki and Sharg Sinnar same observations were obtained. In Singa, highest number were observed also for sheep (~216,000) then cattle (~84,000) and goats (~41,000), then camels (~8,000). in Abu Hougar, still sheep showing the highest (~915,000) compared to goats (~212,000), cattle (~118,000) and finally camels (~16,000)

Table 3.3.1 Animal distribution in different localities in Sinnar state (2016)

Localities	Cattle	Sheep	Goats	camels	Total
Shargh Sinnr	93,942	103,114	116,485	6,852	320,375
Sinnar	187,867	293,621	187,652	11,191	680,331
El Dinder	172,316	701,400	304,360	291,181	1,469,258
Singa	84,641	216,128	41,952	8,647	315,369
Abu Hougar	118,207	915,186	212,197	16,594	1,262,183
El Dali	313,743	2,605,475	697,209	128,336	3,744,764
El Souki	115,551	299,889	89,332	3563	508,335
Total	1,050,237	5,135,801	1,649,176	466,361	8,300,575

Table 3.3.2. Animals daily and annual demands for biomass for Sinnar state localities (2016)

Localities	Animals	Daily Biomass Demand (Kg)	Annual Biomass Demand (Tonnes)
Abu Houjar	Camels N =165,94	107,861	39,369
	Cattle N =118,207	537,841	196,312
	Goats and sheep N = 1,127,383	1,410,426	514,805
Total			**750,487**
El Dali	Camels N =128,336	834,184	304,477
	Cattle N =313,743	1,427,530	521,048
	Goats and sheep N = 3,302,684	4,112,314	1,500,994
Total			**2,326,520**
	Camels N= 291,181	1,892,676	690,826

El Dindir	Cattle N= 172,316	784,037	286,173
	Goats and sheep N = 1,005,760	4,077,154	1,488,161 **2,465,152**
Total			
El Souki	Camels N=3563	23,159	8,453
	Cattle N=115,551	525,757	191,901
Total	Goats and sheep N = 389,221	483,761	176,572 **376,927**
Sharq Sinnar (Eastern Sinnar	Camels N= 6852	44,538	16,256
	Cattle N=93,942	427,436	1,560,14.2
Total	Goats and sheep N = 219,599	2,858,192	1,04,3240 **1,215,510** 20,515
Sinja	Camels N= 8647	56,205	
	Cattle N= 84,641	385,116	140,567
Total	Goats and sheep N = 258,080	324,596	118,477 **279,560** 2,825
Sinnar	Camels N=11,191	7,741	
	Cattle N=187,867	854,794	31,000
Total	Goats and sheep N = 481,273	576,865	210,555 **244,381**

3.3.3 BIOMASS FROM RANGELANDS AND CROP RESIDUES

It could be shown that from Table 3.3.3 crop residues could provide more than 100% for Singa followed by 68% for Abu Hougar, the rest of the localities showed very little and similar percentages

Table 3.2.3 Biomass sources from crop residues and rangeland (Ton) at Sinnar state in 2016

LOCALITY	Projected Crop Residue (Summer Season)	Projected Biomass from Rangelands (NCNF Vegetation Summer Season)	Percent crop residue
	Ton	**Ton**	**Percent (%)**
Abu Hougar	409,684	599,028	68
El Dali	1,222,256	42,756,840	2.9
El Dindir	1,166,666	33,553,850	3.5
El Souki	303,722	779,382	3.9

Sharq Sinnar (Eastern Sinnar)	439,529	480,5176	9.1
Sinja	666,666	126,547	526
Sinnar	940,276	24,314,112	3.9

3.4.1 ANIMAL POPULATION

Animal population distribution in the different localities of Sinnar state is shown in table 3.4.1, showed that in Sharg Sinnar, sheep population was the highest (~101,000) compared to goats (~114,000), cattle population was higher (~920,000) than camels (~6,000). In Sinnar, sheep still maintained the highest population (~289,000), cattle and goats showed nearly the same number (~187,000), camels were the lowest (~11,000) in number. In El Dinder, sheep was maintained as the highest (~697,000), goats (~298,000) with camels here was bigger in number (~285,000) compared to cattle (~168,000). In Singa, sheep population was the highest (~214,000) compared with goats (~41,000), while cattle population was higher (~82,000) than camels (~8,000). In Abu Hougar the order of populations were as: 912,000, 207,000, 115,000 and 16,000 for sheep, goats, cattle and camels respectively. In El Dali, sheep populations exceeded 2 million, then goats which showed higher population (~683,000) than cattle (~307,000) and camels (~125,000). In El Souki the sheep population was the highest (~297,000), then cattle (~113,000), then goats (~87,000) and finally camels (~3,000)

Generally, El Dali, hosted more than 3 millions animal populations, Abu Hougar and El Dinder then Sinnar (~668,000) and El Souki (500,000) and finally Sharg Sinnar (314,000)

3.4.2 ANIMALS DAILY AND ANNUAL DEMANDS FOR BIOMASS

Daily (kg) or annual (ton) biomass demands by animals is shown in table 3.4.2. Demands could always be matched with numbers. In Abu Hougar, cattle showed the highest demand (~192,000 tons), then camels (~38,000 tons) and small ruminants (~4,000 tons). In El Dali, small ruminants showed the highest demands (~1,400,000), then cattle (500,000) and camels (300,000tons). In El Dinder, camels showed the highest (~600,000 tons), small ruminants (~400,000) and cattle (~200,000 tons). Biomass demands in El Souki, was highest for cattle (~188,000 tons), then small ruminants (~177,000 tons) and camels (~8,000). In Sharg Sinnar, biomass demands was the highest for cattle (~ 151,000 tons), then small ruminants (~91,000 tons) and finally camels (~15,000 tons). In Singa, biomass demands was the highest for cattle (~ 137,000 tons), then small ruminants (~117,000 tons) and finally camels (~20,000 tons). In Sinnar, biomass demands was the highest for cattle (~ 56,000 tons), then small ruminants (~38,000 tons) and finally camels (~4,000 tons)

Table 3.4.1 Animal population distribution in the different localities of Sinnar state (year 2015)

Locality	Cattle	Sheep	Goats	Camels	Total
Sharg Sinnar	920,63	101,235	114,155	6,714	314,168
Sinnar	184,109	289,863	183,899	10,967	668,839
El Dinder	168,869	697,953	298,272	285,357	1,450,454
Singa	82,948	214,435	41,112	8,474	346,970
Abu Hougar	115,842	912,821	207,953	16,262	1,252,880
El Dali	307,468	2,599,200	683,264	125,769	3,715,702
El Soukii	113,240	297,578	87,545	3,491	501,855
Total	1,029,232	5,114,796	1,616,192	457,033	8,217,255

Table 3.4.2. Animals daily and annual demands for biomass for Sinnar state localities (2015

Localities	Animals	Daily Biomass Demand (Kg)	Annual Biomass Demand (Tonnes)
Abu Houjar	Camels N =16,262	105,703	38,581
	Cattle N =115,842	527,085	192,386
Total	Goats and sheep N = 1,120,774	402,940	4,835 **147,073**
El Dali	Camels N=125,769	817,500	298,387
	Cattle N =3,074,68	1,398,980	510,627
Total	Goats and sheep N =3,282,464	4,089,555	1,492,688 **2,301,703**
El Dindir	Camels N =285,357	1,854,823	677,010
	Cattle N =1,688,69	768,357	280,450
Total	Goats and sheep N = 996,224	1,217,544	444,403 **1,401,864**
El Souki	Camels N= 3,491	22,696	8,284
	Cattle N= 113,240	515,242	188,063
Total	Goats and sheep N = 385,123	477,898	174,433 **370,780**
Sharq Sinnar (Eastern Sinnar	Camels N= 6714	43,647	15,931
	Cattle N= 920,63	418,887	152,893
Total	Goats and sheep N = 215,390	250,327	91,369 **260,194**
Sinja	Camels N= 8,294	55,081	20,104
	Cattle N=8,474	377,414	137,756
Total	Goats and sheep N = 255,547	321,523	117,356 **275,216**
	Camels N =10,967	13,160	4,803
	Cattle N = 1,841,09	154,652	56,448

Sinnar **Total**	Goats and sheep N = 473,762	104,875	38,279 **99531.36**

3.4.3 BIOMASS FROM RANGELANDS AND CROP RESIDUES

From table 3.4.3. it could be seen that crop residue would provide part of the biomass for the different localities of Sinnar state, it ranged from as high as 62% (Abu Hougar) to 38 and 17% for El Souki and Singa respectively. The other localities showed very little supply.

Table 3.4.3. Biomass sources from crop residues and rangeland (Ton) at Sinnar state in 2015

LOCALITY	Projected Crop Residue (Summer Season)	Projected Biomass from Rangelands (NCNF Vegetation Summer Season)	Percent crop residue
	Ton	**Ton**	**Percent (%)**
Abu Hougar	355,276	570,682	62
El Dali	1,308,333.3	34,429,604	3.8
El Dindir	1,241,769.2	29,583,382	4.1
El Souki	272,607.2	702,297	38
Sharq Sinnar (Eastern Sinnar)	24,641.0	2,357,188	1.0
Sinja	233,845.3	136,180	17
Sinnar	25,641	11,750,972	0.21

3.5 YEAR 2014

3.5.1 ANIMAL DISTRIBUTION IN THE DIFFERENT LOCALITIES OF SINNAR STATE

For the year 2014 and as shown by animal distribution in the different localities of Sinnar state (table 3.5.1), In Sharg Sinnar sheep the highest population (992,000), then goats (111,000), cattle (90,000) and camels (6,000). In Sinnar more than 2 millions of sheep were found, similar numbers of cattle and goats (180,000) and low numbers for camels (10,000). In El Dinder, sheep still maintained higher number (~683,000) with lower number for goats (~292,000) and higher number for camels (279,000) than cattle (~180,000). In Singa, sheep still showed the highest number (~210,000) compared with goats (~40,000), cattle population was higher (~80,000) compared with camesl (8,000). In Abu Hougar, sheep highest population (~894,000) as compared with goats (~203,000) while cattle showed higher (~113,000) compared with camels (15,000). In El Dali sheep population exceeded 2 millions as compared with goats (~669,000) and cattle population was higher (~300,000) compared with camels (~123,000). Generally, El Dali hosted more than 3 millions of animals, while Abu Hougar and El Dinder hosted more than 2 millions then Sinnar (~666,000) and and El Souki (~440,000), then about 300,000 for the remaining localities.

3.5.2 ANIMALS DAILY AND ANNUAL DEMANDS FOR BIOMASS

Daily and annual biomass demand by animals as compared by their type and numbers, is shown in table 3.5.2. In Abu Hougar sheep and goats showed the highest population followed by camels and cattle and (500,000, 378,000, 188,000 tons, respectively). Same trends were observed in El Dali, with nearly same quantities, except camel biomass was very low (20,000). In El Dinder, camels demands were more than 6 million tons and more than 4 million tons for small ruminants with less demands for cattle the demand was about 300,00. In El Souki the order for demands were:103,000, 95,000, 4,000 for cattle, small ruminants and camels respectively. Similar trends were obtained in Sharg Sinnar as cattle also showed the highest

demands (~150,000), then small ruminats (~90,000) and camels with low demand (~15,000 tons). In Singa, cattle and small ruminants showed nearly same demands (~100,000 tons) camel with lower demands (~19,000). In Sinnar, the order was: ~300 tons for cattle, 200,000tons for small ruminants, and 25,000 tons.

In general, El Dali and El Dinder supported more than 1 million biomass (tons), then Abu Hougar (~700,000 tons), the rest of the localities hosted biomass between 300,000 and 200,000 tons

Table3.5.1 Animal distribution in the different localities of Sinnar state 2014

Locality	Cattle	Sheep	Goats	Camels	Total
Sarghsinnar	90,221	992,10.5	111,872	6,580	307,885
Sinnar	180,427	2,840,66	180,221	10,747	655,462
EL Dinder	165,492	683,994	292,307	279,650	1,421,445
Singa	81,289	210,146	40,290	8,304	340,031
Abu huggar	113,526	894,565	203,794	15,936	1,227,822
Eldali	301,318	2,547,216	669,599	123,253	3,641,388
El Soukii	110,975	291,626	85,794	3,421	491,818
Total	1,008,647	5,012,500	1,583,868	447,893	8,052,909

Table 3.5.2. Animals daily and annual demands for biomass for Sinnar state localities (2014)

Localities	Animals	Daily Biomass Demand (Kg)	Annual Biomass Demand (Tonnes)
Abu Houjar	Camels N = 15,936	103,589	378,10.3
	Cattle N= 113,526)	516,543	188,538
Total	Goats and sheep N = 1,098,359	13,74,881	501,831 **728,180**
El Dali	Camels N = 123,253	801,150	29,241
	Cattle N = 113,526	137,1000.	500,415
Total	Goats and sheep N = 3,216,815	4,007,764	1,462,834 **1,992,491**
El Dindir	Camels N = 279,650	1,817,727	6,634,70.3
	Cattle N = 165,492	752,989	274,841
Total	Goats and sheep N = 976,301	1,193,193	4,355,15.3 **1,373,827**
El Souki	Camels N = 3421	12,489	4,558
	Cattle N = 110,975	283,541	103,492
Total	Goats and sheep N = 377,422	262,991	95,991 **204,043**
	Camels N =6580)	42,774	15,612

Sharq Sinnar (Eastern Sinna	Cattle, N = 90,221	410,509	149,836
	Goats and sheep N = 211,082	245,320	89,542
Total			**254,990**
Sinja	Camels N = 8304	53,979	19,702
	Cattle N = 81,289	369,865	135,001
	Goats and sheep N = 250,436	315,092	115,008
Total			**269,712**
Sinnar	Camels N =10,747	69,860	25,499
	Cattle N = 180,427	820,945	299,645
	Goats and sheep N = 464,287	556,716	203,201
Total			**528,345**

3.5.3 BIOMASS FROM CROP RESDIUES AND RANGELAND

Biomass supply from crop residues accounted for as high as 416%, 96% and 46% in Singa, Abu Hougar and El Souki to negligible percentages for the rest of the localities (Table 4.10.1)

Table 3.5.3 Biomass sources from crop residues and rangeland (Ton) at Sinnar state in 2014

LOCALITY	Projected Crop Residue (Summer Season)	Projected Biomass from Rangelands (NCNF Vegetation Summer Season)	Percent crop residue
	Ton	**Ton**	**Percent (%)**
Abu Hougar	508,615	528,501	96
El Dali	1,637,170	37,160,496	4.4
El Dindir	118,820	26,472,718	0.4
El Souki	293,800	642,675.	46
Sharq Sinnar (Eastern Sinnar)	64,102	4,598,820	0.1
Sinja	470,085	112,864	416
Sinnar	352,564	22,516,008	1.5

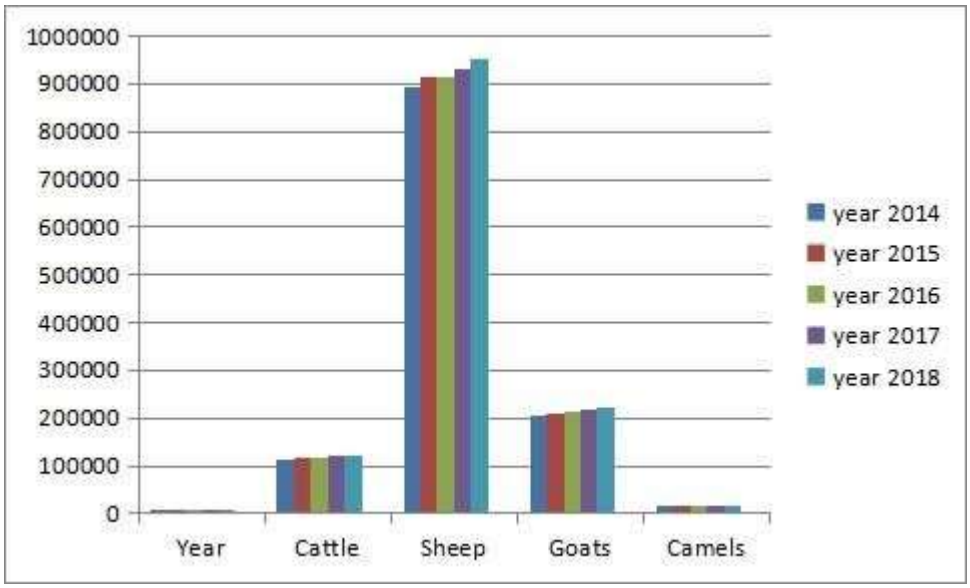
3.6. EFFECT OF YEAR ON ANIMAL POPULATION

Changes in population for different animal species were studied for the different localities at Sinnar state, figure 3.6.1 showed that at Abu Hougar, cattle number changed very slightly from year 2014 to year 2018 there was a steady increase in sheep number for the same years, goats and camels' number did not change much over the years. Sheep number was the highest

followed by goats, cattle and camels. Sheep number was the highest at El Dali, showed slight increase from 2014 – 2018, followed by goats, cattle and camels which did not show any observed increase over the years (figure 3.6.2). At Singa, sheep showed the highest number with steady increase over the years (2014 – 2018), followed by cattle which also showed slight increase over the years, then goats and finally camels with very minor increase over the year (figure 3.6.3).

In Dinder, a clear drop was observed in all animal numbers in the year 2018, throughout the other years, all animals maintained their number with slight increase especially in sheep (figure 3.6.4). At El Souki, (figure 3.6.5) sheep population was the highest and increased steadily over the years, cattle came the next, then goats with slight changes over the years, same was for camels which showed the least population. At Sinnar there was a steady increase for sheep, cattle and goats, while camels maintained nearly the same number over the years (figure 3.6.6). Same observations were obtained in Sharg Sinnar (figure 3.6.7)

Figure 3.6.1 Animal populations for the different species at Abu Hougar



3.6.2. El Dali

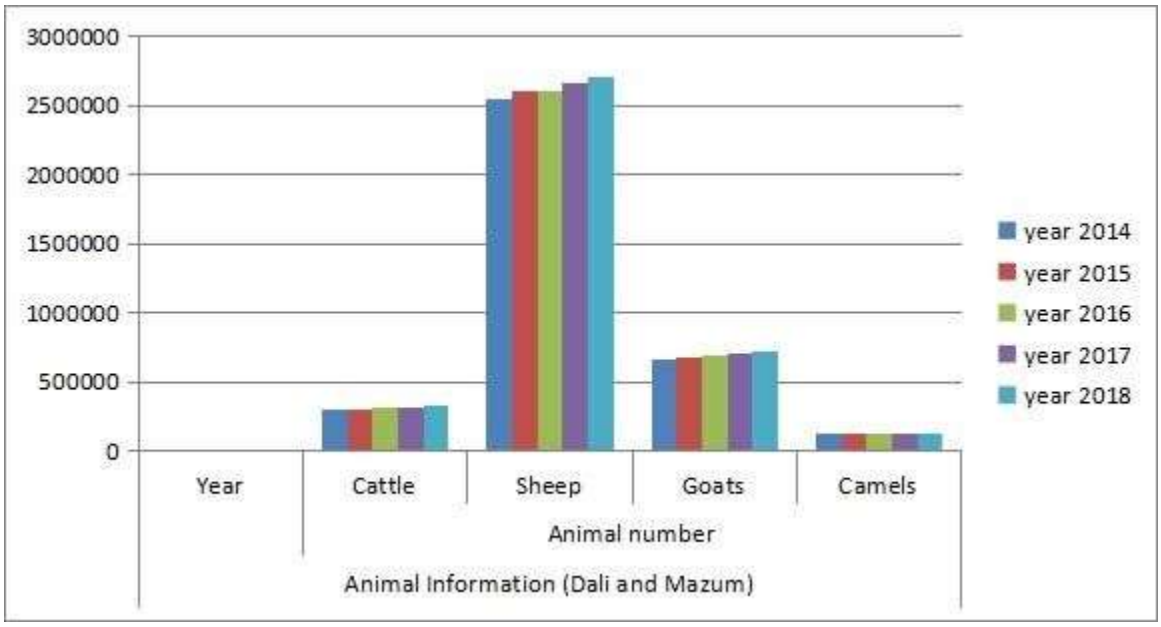
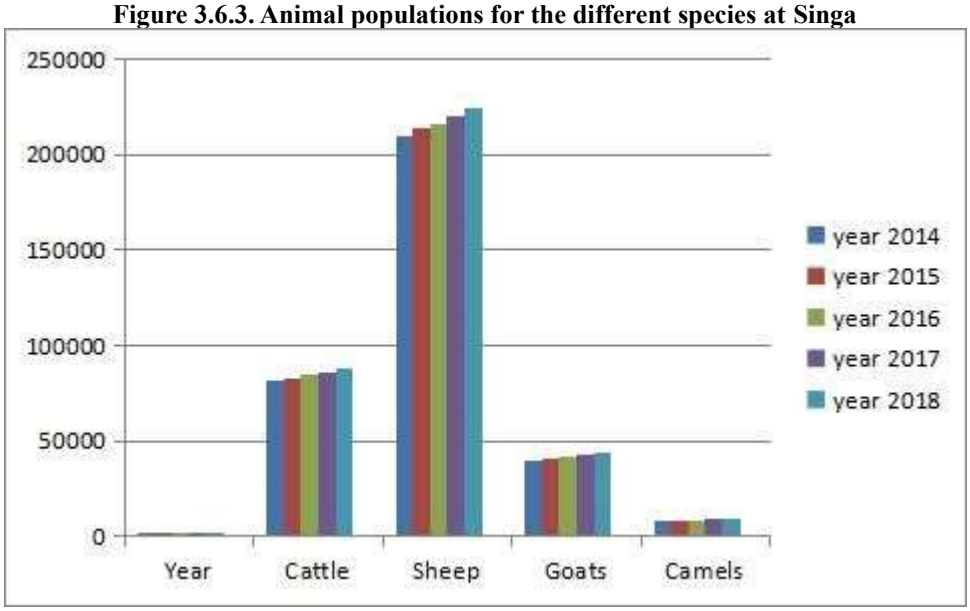


Figure 3.6.3. Animal populations for the different species at Singa



3.6.4.El Dinder

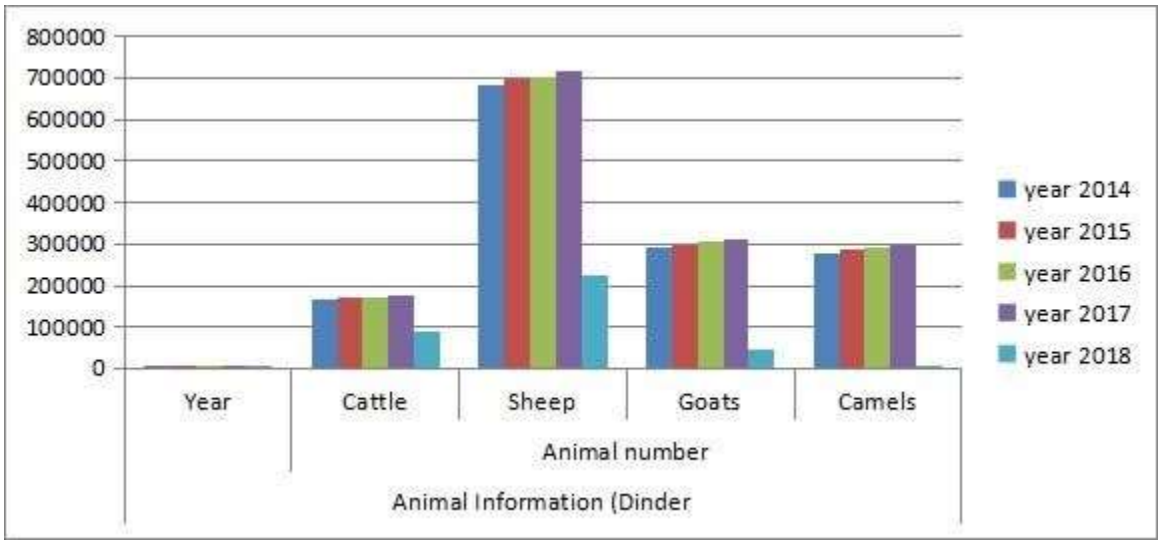
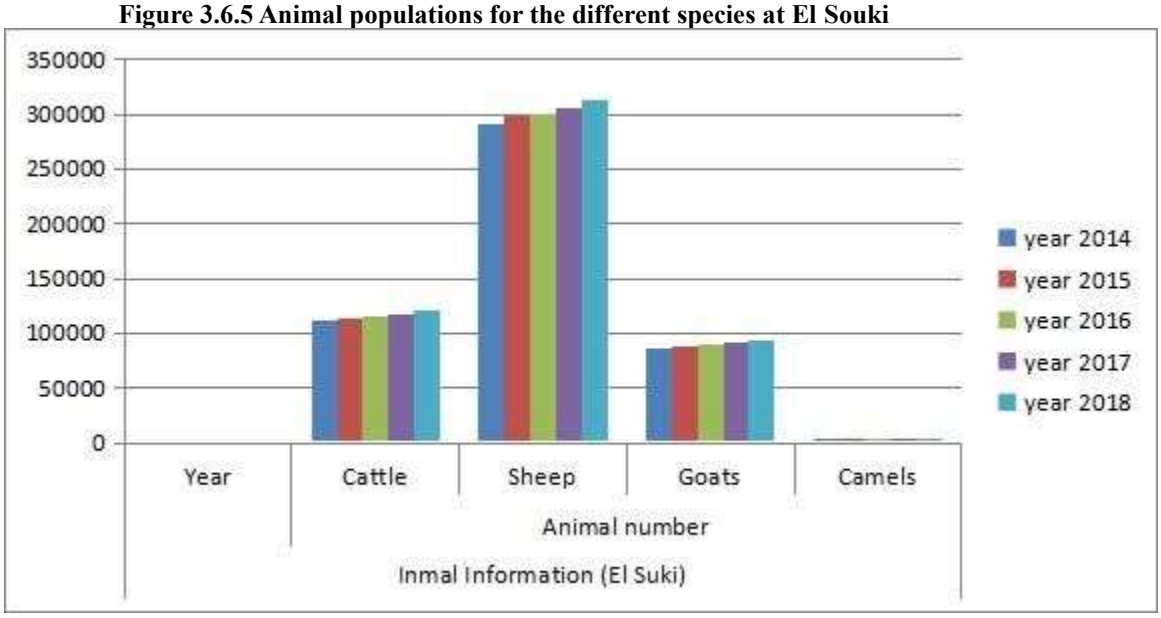


Figure 3.6.5 Animal populations for the different species at El Souki



3.6.6.Sinnar

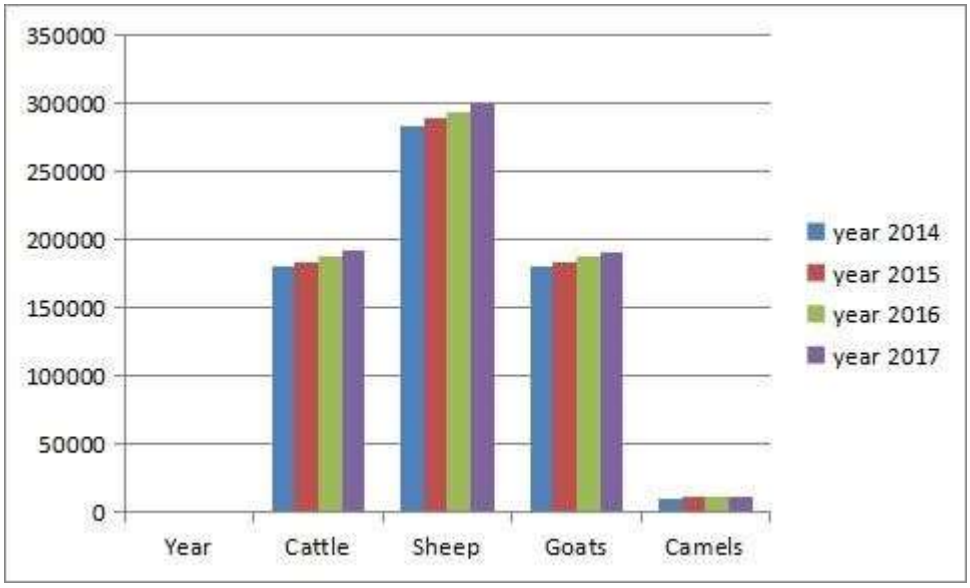
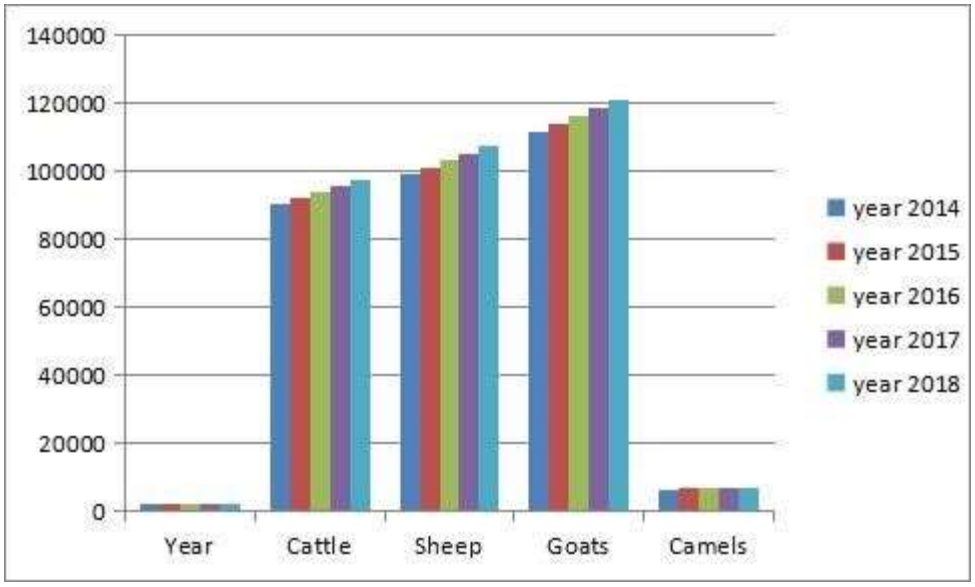


Figure 3.6.7. Animal populations for the different species at Sharg Sinnar



3.7 ANIMAL EXPERIMENTATION (CROP RESIDUE NUTRITIVE VALUE IMPROVEMENT)

3.7. 1 FOOD INTAKE

Effect of treated straw with 5% urea on food intake of lactating goats on their mid of lactation for 4 weeks, showed for the control group (C) there were individual variations through the 4 weeks (Table 3.7.1), but all showed a general trend of gradual increase. For those fed the treated sorghum straw, an opposite trend was observed where goats showed an decrease in intake especially in week 3 then an increase except for goat T5 (Table 3.7.1.1).

When comparing the control group and treated group, a significant difference ($P \leq 0.0227$) was observed in the food intake which decreased in the goats fed the treated straw compared to those fed the untreated one (Table 3.7.1.2).

3.7.2 MILK YIELD

The milk yield for the lactating goats through the 4 weeks increased steadily for the individual animals but the average showed little changes in yields through this period (Table 3.7.2).. For the goats fed the treated straw, there was a sudden decrease in week 3 then an increase, however, the average for the 5 goats showed an increase in yield within the 4 weeks (Table 3.7.2.1).

As for the pair t test significant increase in milk yield was obtained for both week 3 ($P \leq 0.05$) and week 4 ($P \leq 0.01$) (Table 3.7.1.2)

Table 3.7.1: Feed intake of for control (C) lactating goats fed untreated sorghum straw (g)

Animals ➡	C1	C2	C3	C4	C5	Average ±SD
Weeks ⬇						
1	1843 1814	1757	1514	1757	1737±130.09	
2	1429 1629	1443	1586	1500	1517±87.768	
3	1086 1329	1271	1314	1171	1234±103.28	
4	886 1814	1757	1514	1757	1545±386.49	

Table 3.7.1.1 Effect of treated sorghum straw on food intake (g) in lactating goats (T)

Animals ➡	T1	T2	T3	T4	T5	Average ±SD
Weeks ⬇						
1	1757	1600	1714	1457	1786	1663±135.07
2	1579	1560	1336	1114	1321	1386±192.45
3	980	1371	1086	957	986	1076±172.19
4	921	964	1200	900	771	951±156.58

Table 3.7.1.2 Paired t test for food intake for control animals and animals fed treated sorghum straw

weeks	**Control animals**					**Treated**					
	C1	C2	C3	C4	C5	T1	T2	T3	T4	T5	**±SE**
1	1843	1814	1757	1514	1757	1757	1600	1714	1457	1786	100.47
2	1429	1629	1443	1586	1500	1579	1560	1336	1114	1321	39.751
3	1086	1329	1271	1314	1171	980	1371	1086	957	986	64.716
4	886	1814	1757	1514	1757	921	964	1200	900	771	175.59*

Values within the same row are tested for significance

*$P \leq 0.0227$

Table 3.7.2 Milk yield (lb) in lactating goats fed untreated sorghum straw

Animal ➡	C1	C2	C3	C4	C5	**Average ±SD**
Weeks ⬇						
1 1.53	1.80	2.60	2.80	2.59	2.64±0.561 4 2	2.68 2.67 2.50 2.56
2.56 2.59±0.0780 3	2.69	2.97	2.80	2.06	2.77	2.65±0.3495
4	2.59	2.67	2.55	1.89	2.56	2.45±0.3177

Table 3.7.1.1 Milk yield (lb) in lactating goats fed treated sorghum straw

Animal ➡	T1	T2	T3	T4	T5	**Average ±SD**
Weeks ⬇						
1	3.16	4.43	1.90	2.87	2.90	3.052±0.9075

2	4.71	7.43	3.07	2.90	4.93	4.608±1.8276
3	5.10	6.92	3.24	3.27	4.96	4.698±1.5275
4	5.17	6.84	3.15	3.47	5.16	4.758±1.4925

Table 3.7.1.2 Pair t test for milk yield for animals fed untreated straw (control, C) and those fed treated straw (T)

	Control					Treated					
Weeks	C1	C2	C3	C4	C5	T1	T2	T3	T4	T5	±SE
1	153	1.80	2.70	2.80	2.59	3.16	4.43	1.90	2.87	2.90	0.5941
2	267	2.67	2.50	2.55	2.56	4.71	7.43	3.07	2.90	4.93	0.7923
3	269	2.97	2.40	2.06	2.77	5.10	6.92	3.24	3.27	4.96	0.5940*
4	259	2.67	2.00	1.89	2.56	5.17	6.84	3.15	3.47	5.16	0.5947**

***significant at <0.05, **significant at <0.01**

Discussion

Livestock water productivity (LWP) was estimated as a ratio of livestock's beneficial outputs to water depleted, it differs from water or rain use efficiency because it looks at water depletion rather than water input. Increasing LWP can help achieve more production per unit of water depleted. To increase water productivity we have to look at food sourcing (crop residue), conserving water, and optimal spatial distribution of animals. Higher water productivity reduces the need for additional water and land resources in irrigated and rainfed systems (Hengsdijk *et al*., 2006). LWP showed significant and positive correlation with area of cultivated crop land (r = 0.26), livestock feed physical water productivity (r = 0.50) and farm water productivity (crop livestock) (r = 0.49) at household level (Peden *et al.*, 2007). Although crop residues have low nutritive value, but could be improved certain processing to upgrade their values. In this study, crop residues could be the best supplement to bridge the gap of animals' feed when the rangelands are greatly deteriorated during the summer seasons.

It could be revealed from the results that crop residues for more of the localities provide more than 100% as a feed source for animals. The differences between the localities could be due to the extent of expansion of mechanized farming. The difference in biomass demands by the animals for the different localities showed the rate of increase of demand could be correlated with the number of animals as will be explained in more details later.

In the year 2017, crop residue importance as a supplement for the rangeland during the summer season was of less importance although it showed as more as 80% for three localities with negligible percentages for the other localities, For the year 2016, crop residue supply would contribute for more than 100% for Sinnar (526%) and 68% for Abu Hougar (68%) with negligible percentages for the other localities. Supply from rangelands was more than 90% for Sinnar, El Dali and Dinder.Crop residue contribution was important for Abu Hougar (68%) and El El Soukii (38%) with little percentages for the other localities in the year 2015. Contribution from crop residues was a high as 416 % and 96% for Singa and Abu Hougar respectively but small contributions for the other localities in the year 2014.

Most of the localities showed a steady increase in animal number over the years except for El Dinder which showed a clear drop in 2018. Small ruminants especially sheep outnumbered the other animal species except for Sharg Sinnar where cattle number were nearly the same as goats and sheep. For Sinnar herd structure showed similar ratios for cattle and goats and nearly the same to that of sheep. The same was observed for El Soukii but with lower animal numbers. Sheep were dominant in Singa and Dinder

Dairy goats were used in animal experimentation to see the effect of feeding treated sorghum straws with urea as to enhance digestibility and improve milk yield, the results showed although there was a decrease in food intake, but milk yields increased significantly. This would ensure that crop residues if treated with certain treatments would increase animal production. the increase in food intake could be improved by adding molasses.

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